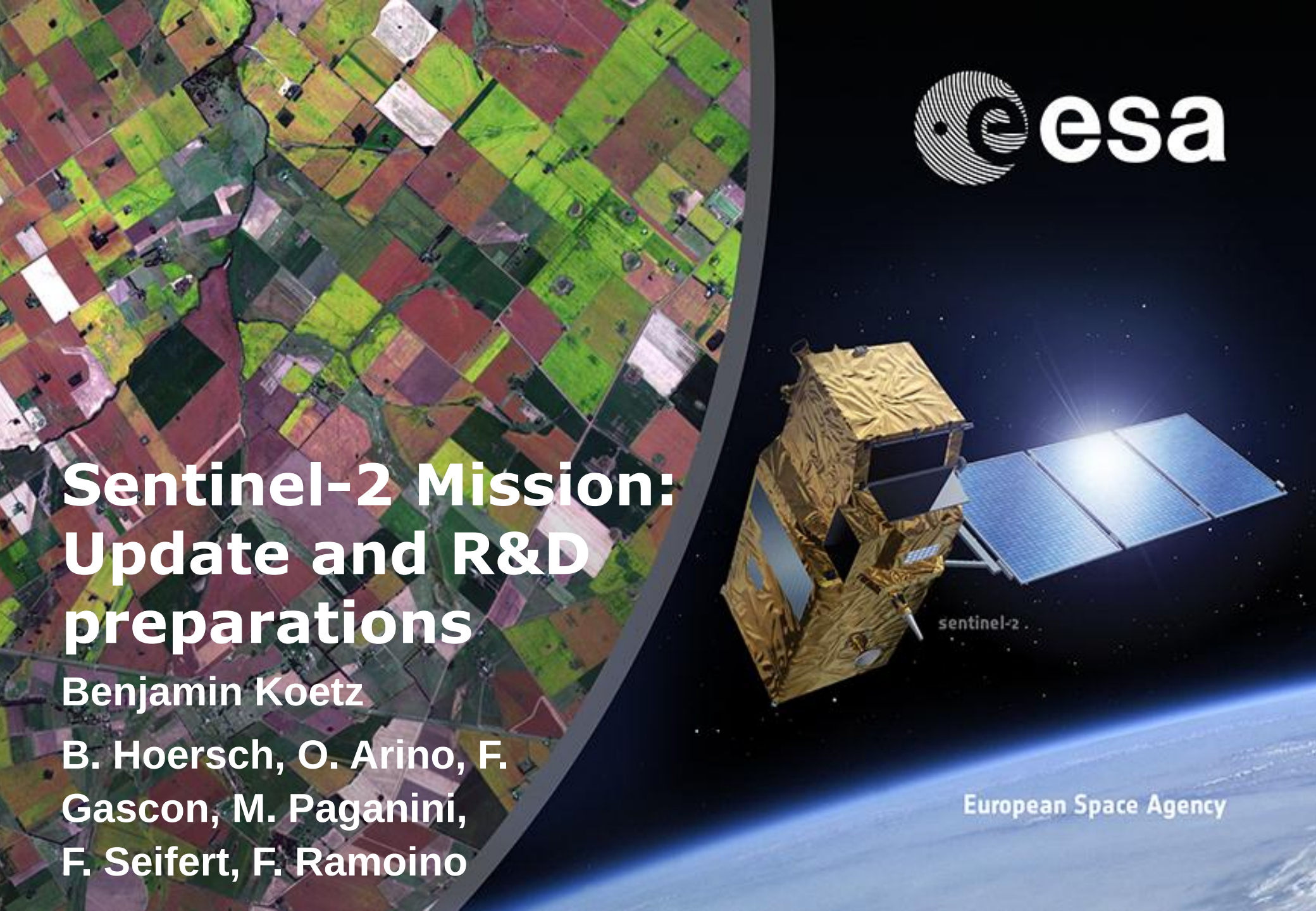


Sentinel-2 Mission: Update and R&D preparations

Benjamin Koetz

B. Hoersch, O. Arino, F. Gascon, M. Paganini, F. Seifert, F. Ramoino

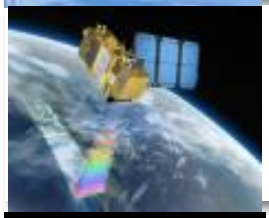
Sentinel Missions
Joint EU-ESA Copernicus Space Programme

Long-term Continuity and Access to suitable EO data

- Free, full and open data policy*

Sentinel 1 – SAR imaging
All weather, day/night application e.g. flood
mapping

2016



Sentinel 2 – Multi-spectra
Land applications: urban
Continuity of Landsat

2015 & 2016

Sentinel **d monitoring**
Wide egetation, sea/land
surfa

2015 & 2016

OPERATIONAL

* Joint EU/ESA Data Policy Principles adopted by ESA member states in Sep '09, EU in 2014

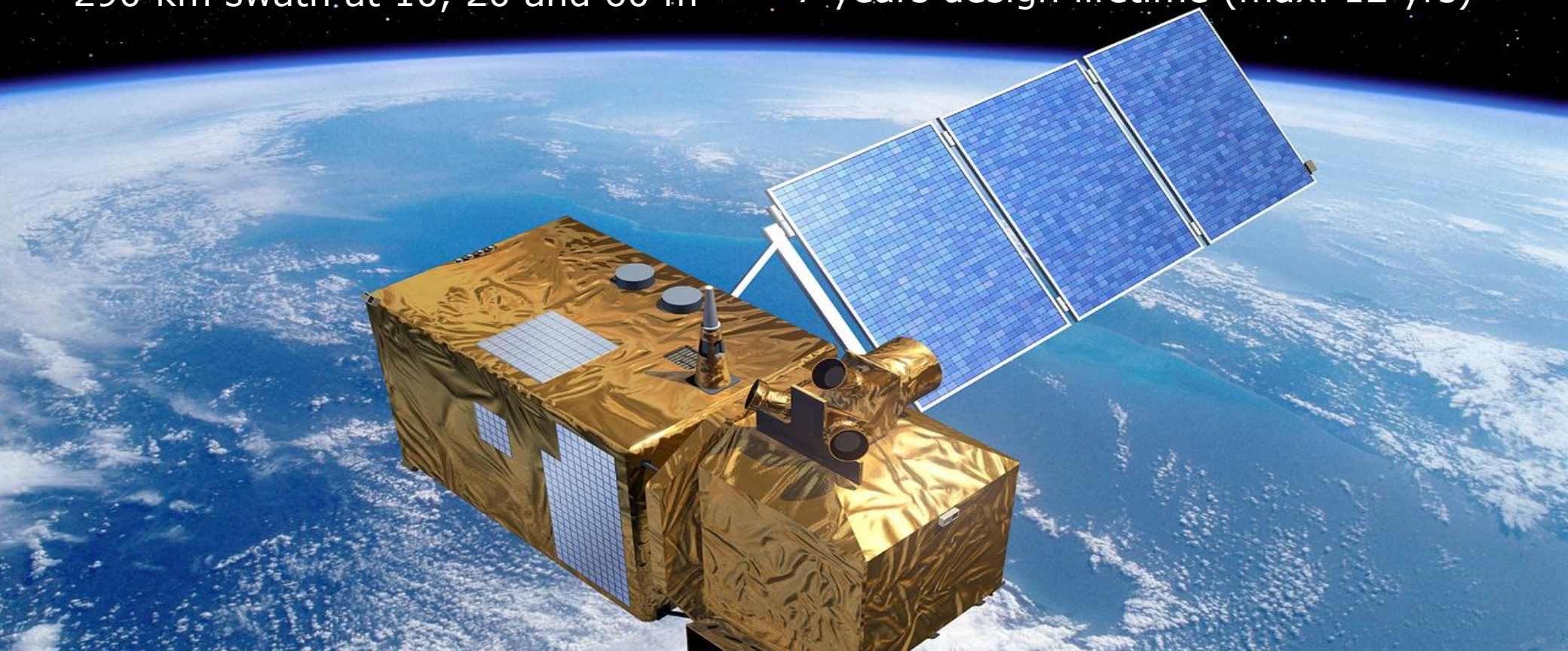
Operational Satellite Observations:
SENTINEL-1 – Start of the Sentinel era

One of the first S1 images (Nambia):
IW mode – 20 m flood extent

Copernicus Sentinel-2

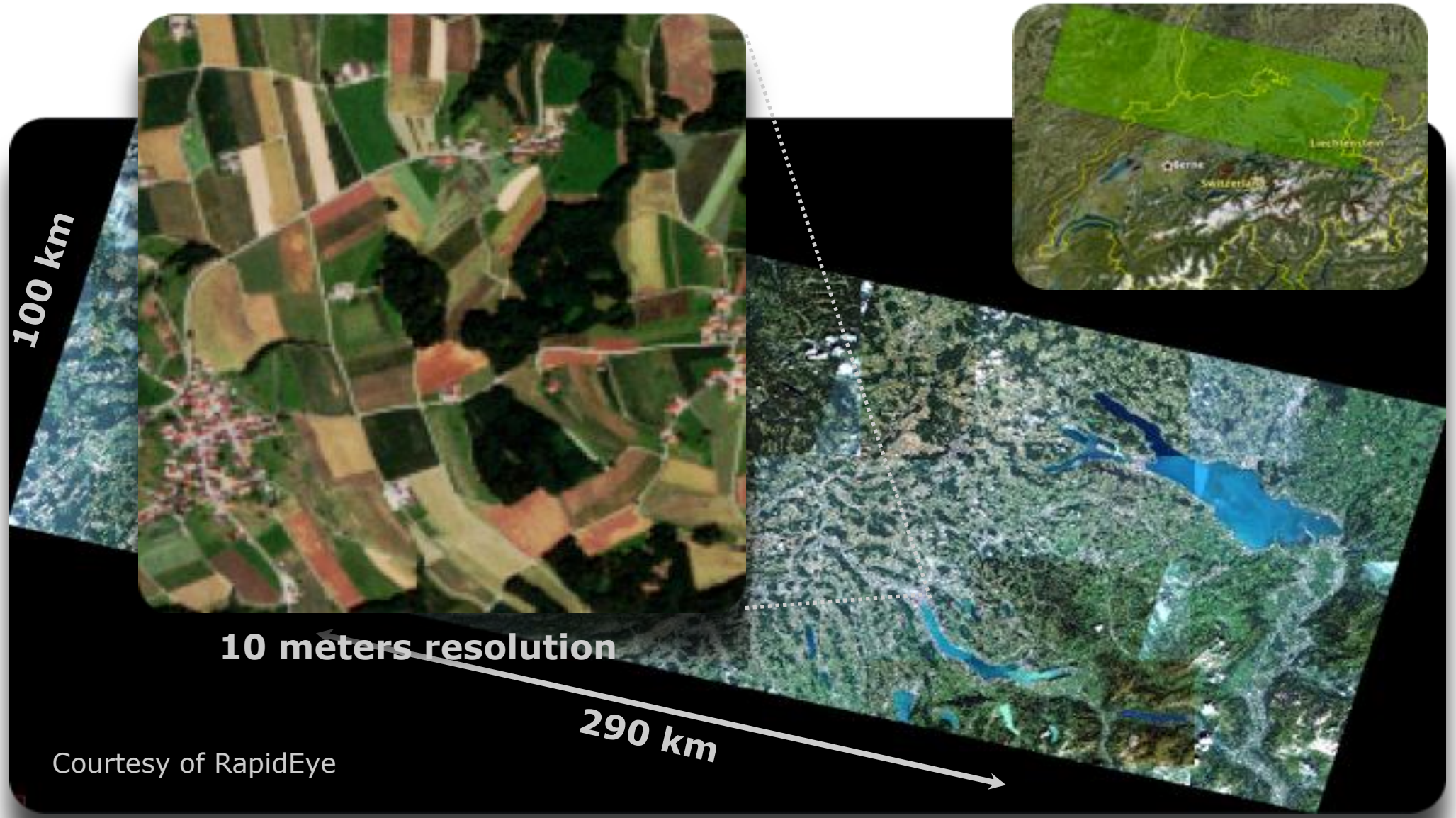
Multispectral High Resolution Optical Imager

- Launch: 2015, 2016, ...
- 13 bands (VIS, NIR & SWIR)
- 290 km swath at 10, 20 and 60 m
- Systematic acq. of all land and coasts
- 5 days repeat cycle with 2 satellites
- 7 years design lifetime (max. 12 yrs)

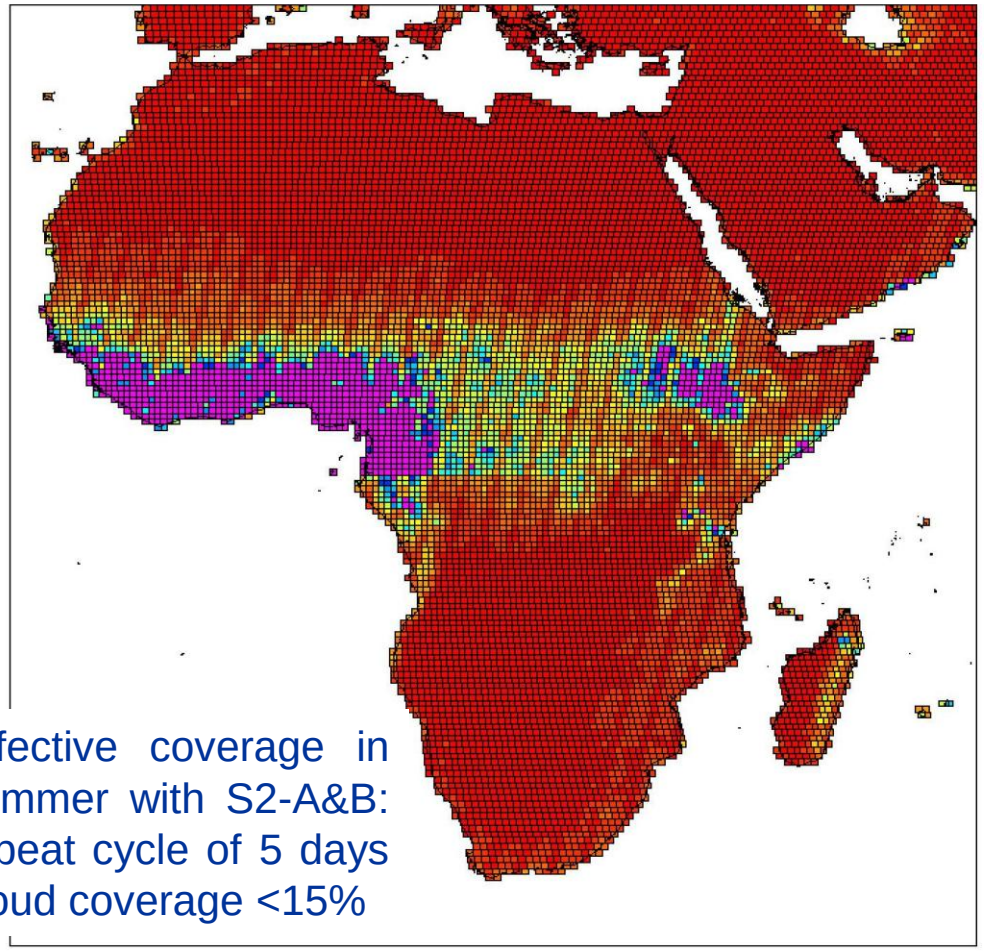


Sentinel-2: Coverage & Resolution

10 m resolution for field scale mapping



Sentinel-2 Revisit Time Capability
5 days revisit for crop dynamics

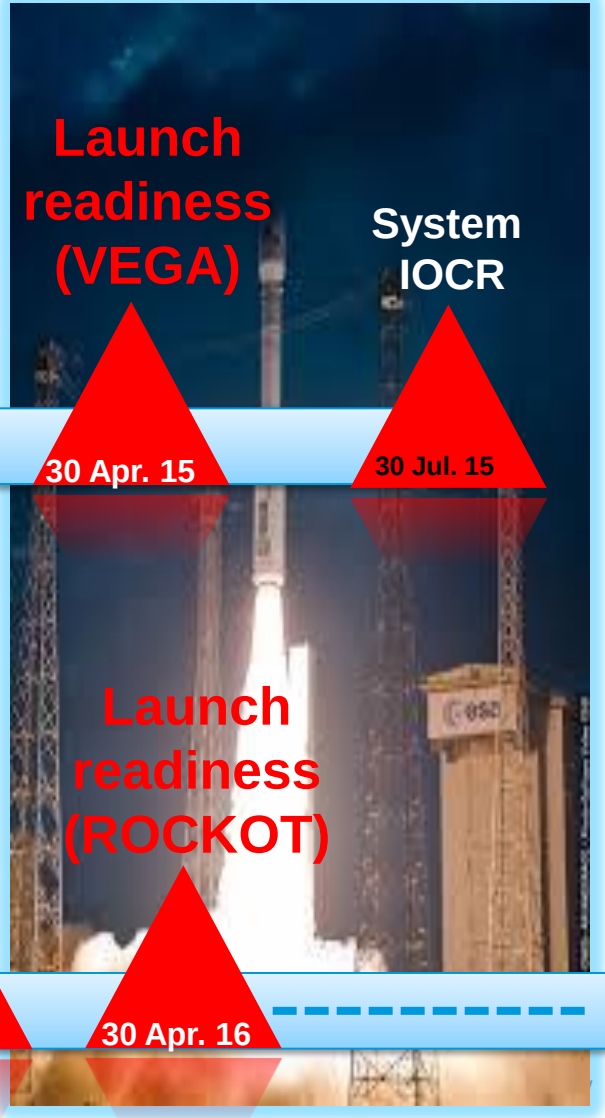


Effective coverage in summer with S2-A&B: repeat cycle of 5 days cloud coverage <15%

South Africa JECAM site: 5 days revisit, February-June 2013 - RapidEye

Monthly cloud free composites possible for most areas

Sentinel-2A: < 1 year to launch
launch not before 30th of April 2015



MSI PFM integration

Satellite arrival at IABG(D)

OCP FM integration

QAR Board

Launch readiness (VEGA)

System IOCR

S2A

21 May 14

8 Aug. 14

30 Nov. 14

15 Mar. 15

30 Apr. 15

30 Jul. 15

MSI integration, Satellite final functional tests

Satellite environmental qualification tests

MSI integration

FAR Board

Launch readiness (ROCKOT)

S2B

15 Jul. 15

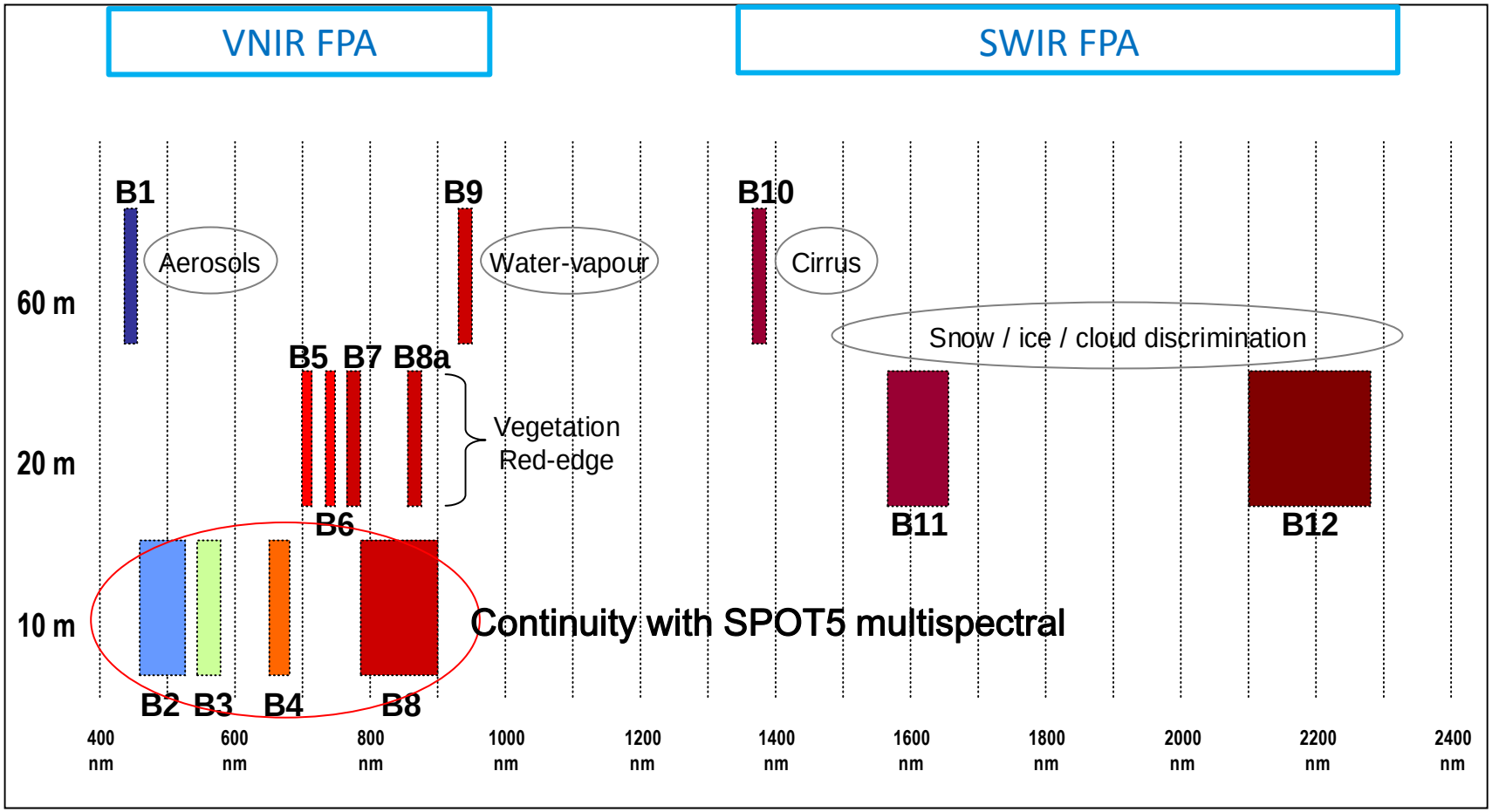
15 Mar. 16

30 Apr. 16

Sentinel-2 development status

Sentinel-2A and -2B platforms at AirbusDS Germany

Sentinel-2: MSI spectral bands



Landsat 8
OLI bands

MSI VNIR SNR performance

MSI mean SNR budget based on VNIR PFM FPA measurements

→ Exceeds the requirement with margin >20% over the full FPA

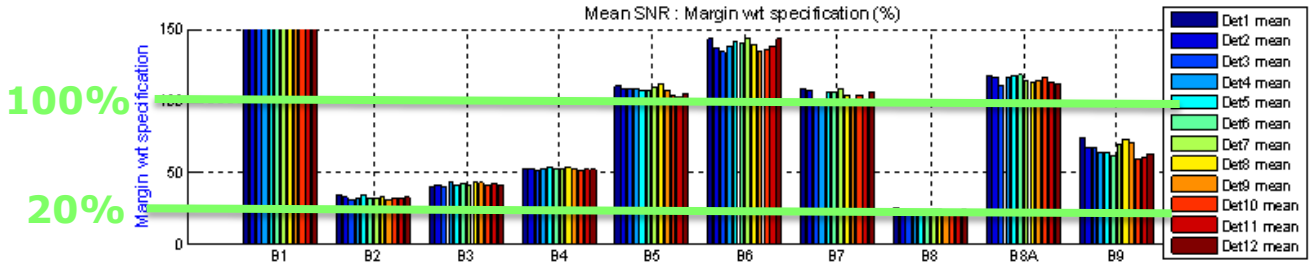
→More than 100% margin for the Red Edge bands

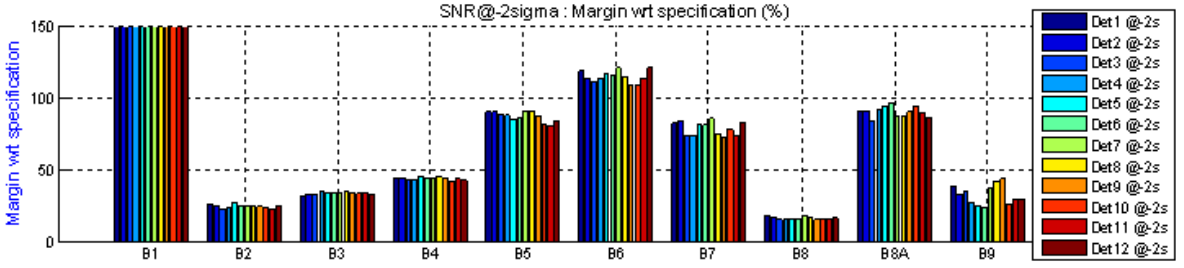
SNR requirements for VNIR bands

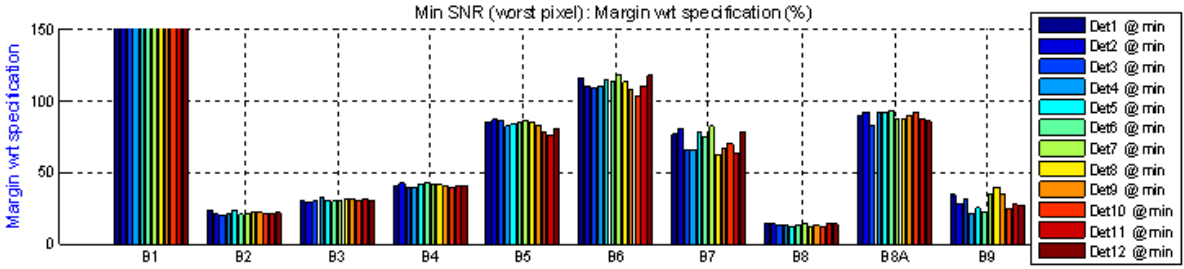
Band	Lmin	Lref	Lmax	SNR
	$W.m^{-2}.sr^{-1}.mm^{-1}$	**$W.m^{-2}.sr^{-1}.mm^{-1}$**	$W.m^{-2}.sr^{-1}.mm^{-1}$	**@ Lref**
B1	16	**129**	588	**129**
B2	11.5	**128**	615.5	**154**
B3	6.5	**128**	559	**168**
B4	3.5	**108**	484	**142**
B5	2.5	**74.5**	449.5	**117**
B6	2	**68**	413	**89**
B7	1.5	**67**	387	**105**
B8	1	**103**	308	**174**
B8a	1	**52.5**	308	**72**
B9	0.5	**9**	233	**114**

SNR measurements for VNIR bands at MSI level

Margin wrt specifications [%]







MSI SWIR SNR performance

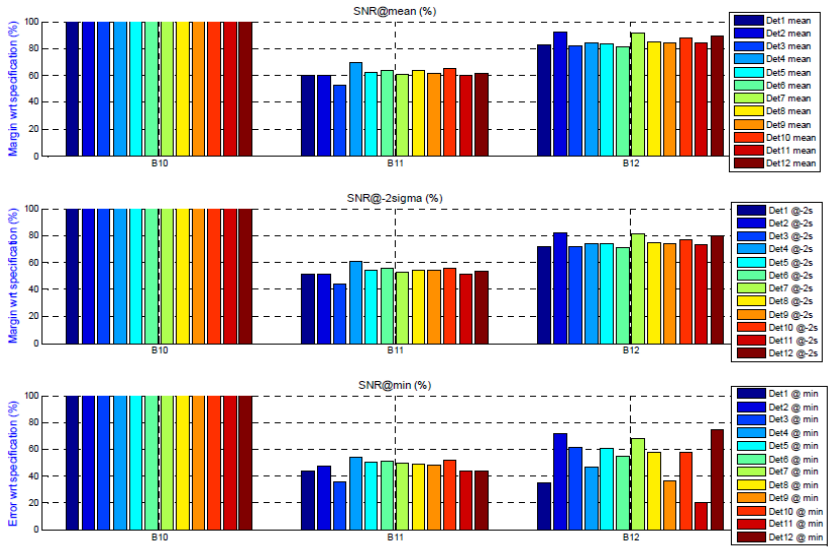
MSI mean SNR budget based on SWIR PFM FPA measurements

→ Exceeds the requirement with margin > 50% over the full FPA @ LRef

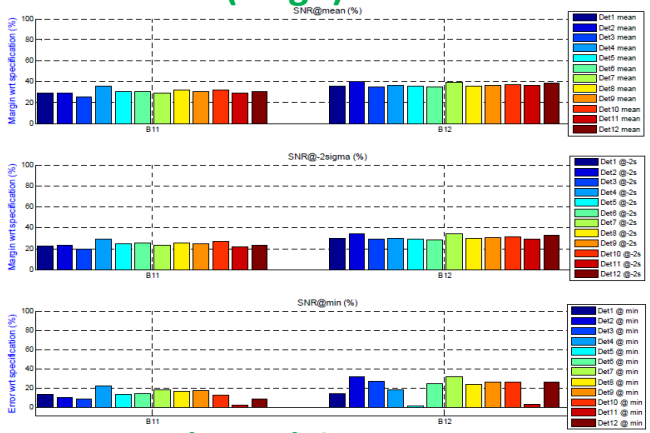
→ Exceeds the requirement with margin > 20% over the full FPA @ Lhigh

→ Consistent performance between test at SWIR FPA and MSI level

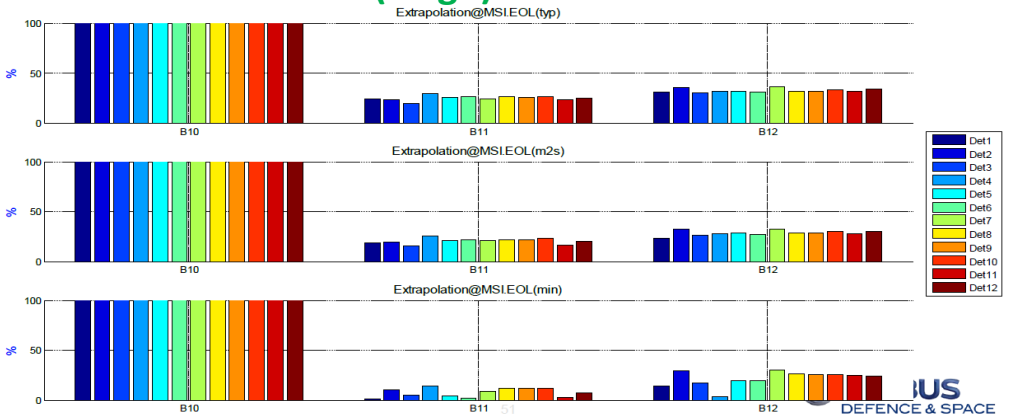
SNR measurements (Lref) for SWIR bands at FPA level



SNR measurements (Lhigh) for SWIR bands at FPA level



SNR measurements (Lhigh) for SWIR bands at MSI level



SNR requirements for SWIR bands

Band	Lref	Lhigh	SNR @ Lref	SNR @ Lhigh
	$W.m^{-2}.sr^{-1}.mm^{-1}$	$W.m^{-2}.sr^{-1}.mm^{-1}$		
B10	6	n/a	50	n/a
B11	4	32	100	504
B12	1.7	11	100	475

Sentinel-2 User Products List

Name	High-level Description	Production	Preservation Strategy	Volume
Level-1B *	Top-of-atmophere reflectances in sensor geometry.	Systematic	Long-term	~27 MB (each 25x23km^2)
Level-1C	Top-of-atmosphere reflectances in cartographic geometry.	Systematic	Long-term	~500 MB (each 100x100km^2)
Level-2A**	Bottom-of-atmosphere reflectance in cartographic geometry	On client side (using Sentinels Exploitation Tool)	N/A	~600 MB (each100x100km^2)

*: The use of Level-1B product requires advanced expertise in geometrical processing.

**: ESA is preparing for systematic L2a processing

Level-1C / Definition

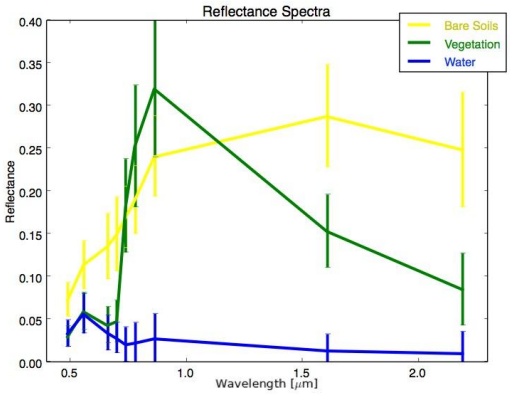
- Top-of-atmosphere (TOA) reflectance in cartographic geometry (UTM/WGS84).
- Image radiometry key features:
  - ✓ Radiometrically corrected data.
  - ✓ Reflectance coded in 12 bits.
  - ✓ Product includes all necessary parameters required to convert the provided reflectance into radiances.
- Image geometry key features:
  - ✓ Orthorectification uses an 90m-resolution DEM.
  - ✓ Sub-pixel multi-temporal registration between images.

100km x 100km tile

Level-2A / Definition

Bottom-of-atmosphere (BOA) reflectance in cartographic geometry (UTM/WGS84)

ESA is preparing for systematic L2a processing

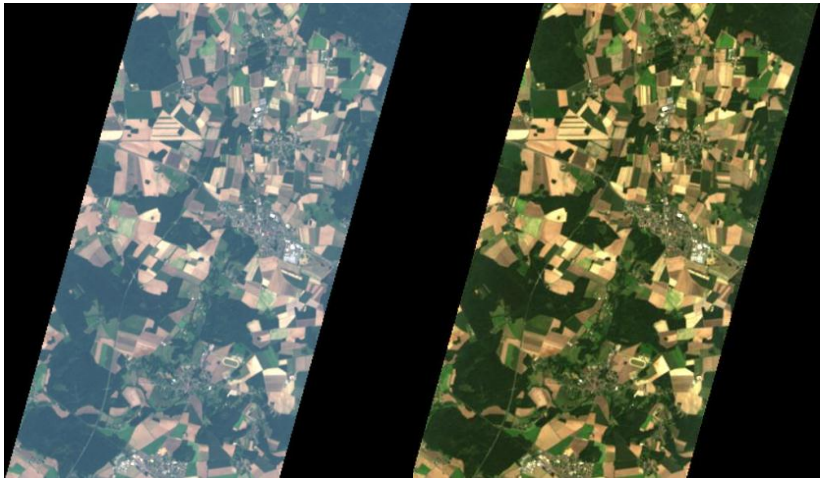


Products additionally include:

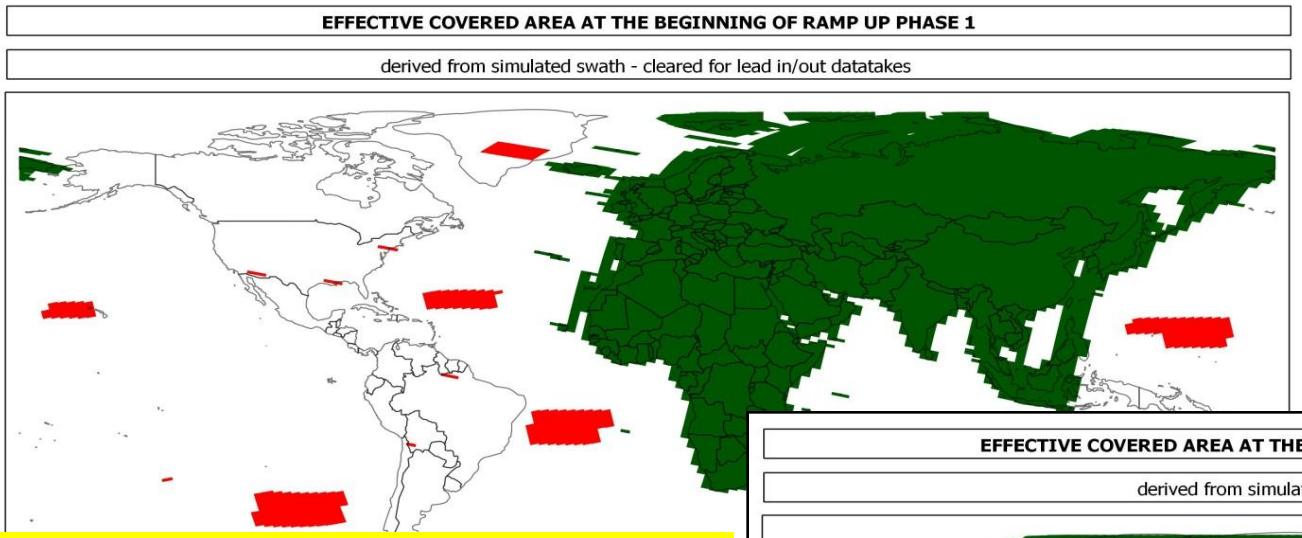
- ✓ Scene Classification Map
- ✓ Water Vapour Map
- ✓ Aerosols Optical Thickness Map

Algorithm includes:

- ✓ Cloud and cloud shadow detection.
- ✓ Cirrus detection and correction.
- ✓ Slope effect correction.
- ✓ BRDF effect correction.



There will be gradual ramp-up until the Full Operational scenario is reached

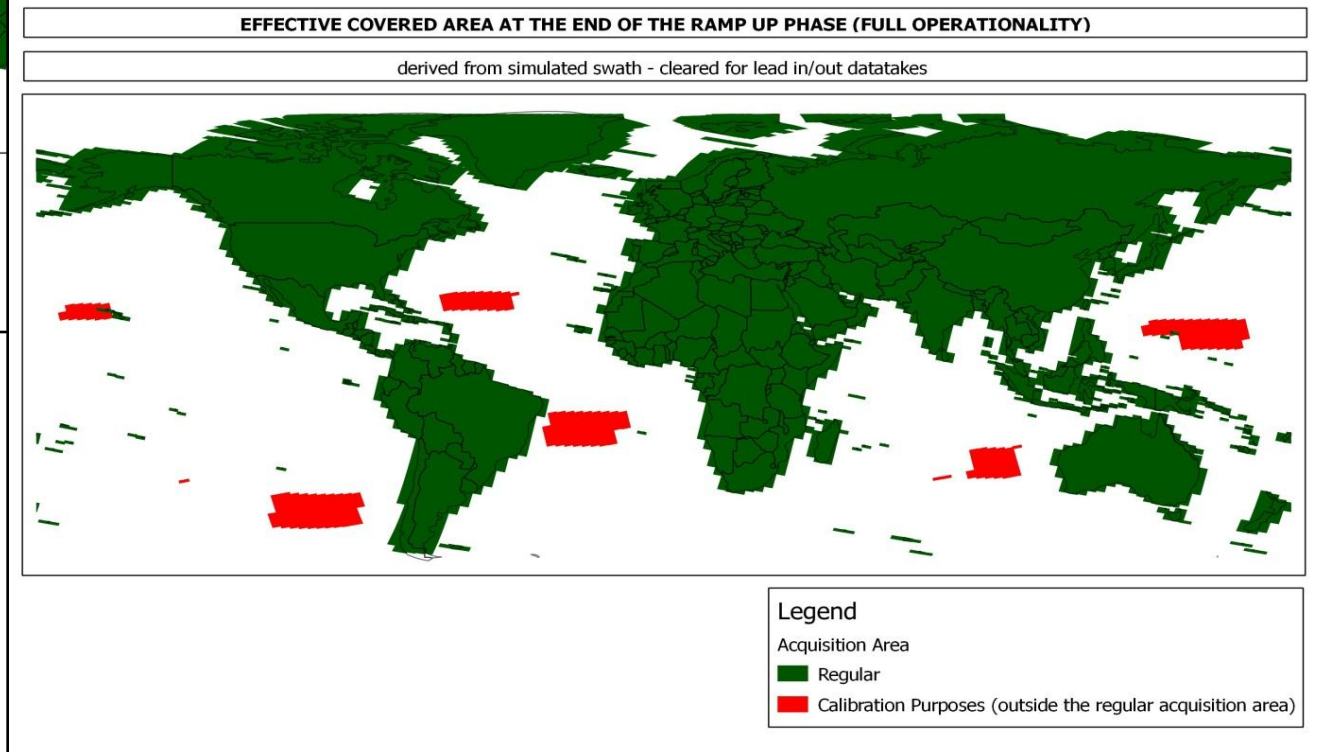


Start of ramp-up phase (after commissioning phase)

- Assuming availability of 2 downlink stations out of 4
- Ensuring coverage of global Cal/Val needs
- Ensuring COPERNICUS CORE datasets needs for Europe/Africa systematically
- Ensuring maximum coverage/orbit length for GRI generation

Products will become available immediately, data quality will be refined until full GRI (Global reference Image) is available

End of ramp-up



Data Access – A major undertaking

A major European Earth Observation Ground Segment design challenge

- **Systematic processing and availability** of the complete acquired data
  - ➔ corresponding to a sustained generation rate (24h/7d) of a continuous stream of

500Mb/s of user products (Sentinel-1,-2,-3 A series)

1700 Gbyte per day from Sentinel-2 (for Level 1C)!

- Distributed interconnected network of centres (improved redundancy)
- Local centre access capacity built on top of a **powerful and scalable network**

Including **Big Data paradigm** and use of innovative solutions

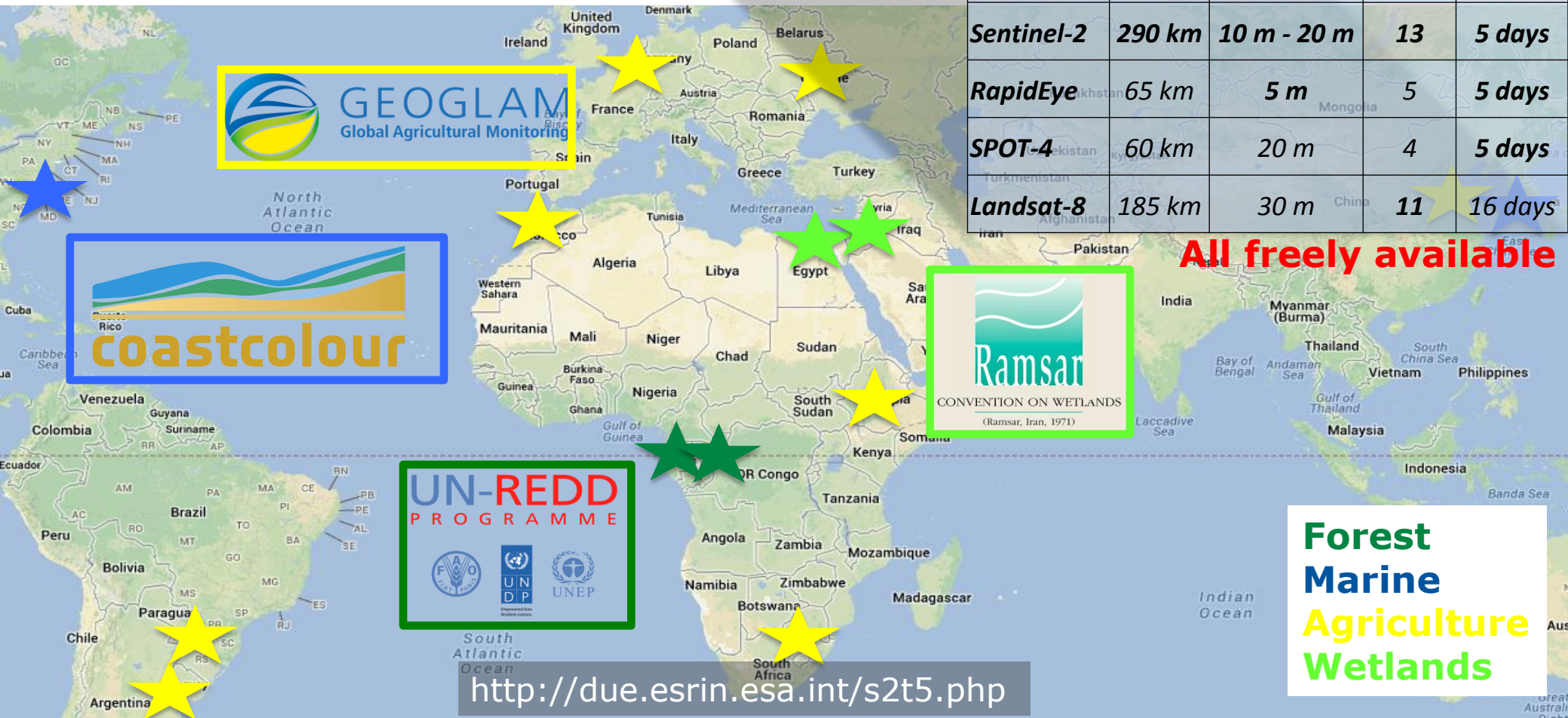
- Progressive inclusion of **Research Support & Hosted Processing services**
- **Enhanced connectivity** to international scientific network (e.g. GEANT)
- **Federation of distributed data pick-up points** to optimise proximity to end users

Simulated Sentinel-2 Time Series
(in partnership with Take 5 initiative of CNES/CESBIO)

- 14 ESA sites, **globally distributed with international partners**
- Multi-sensor & multi-temporal data set (February-June 2013)

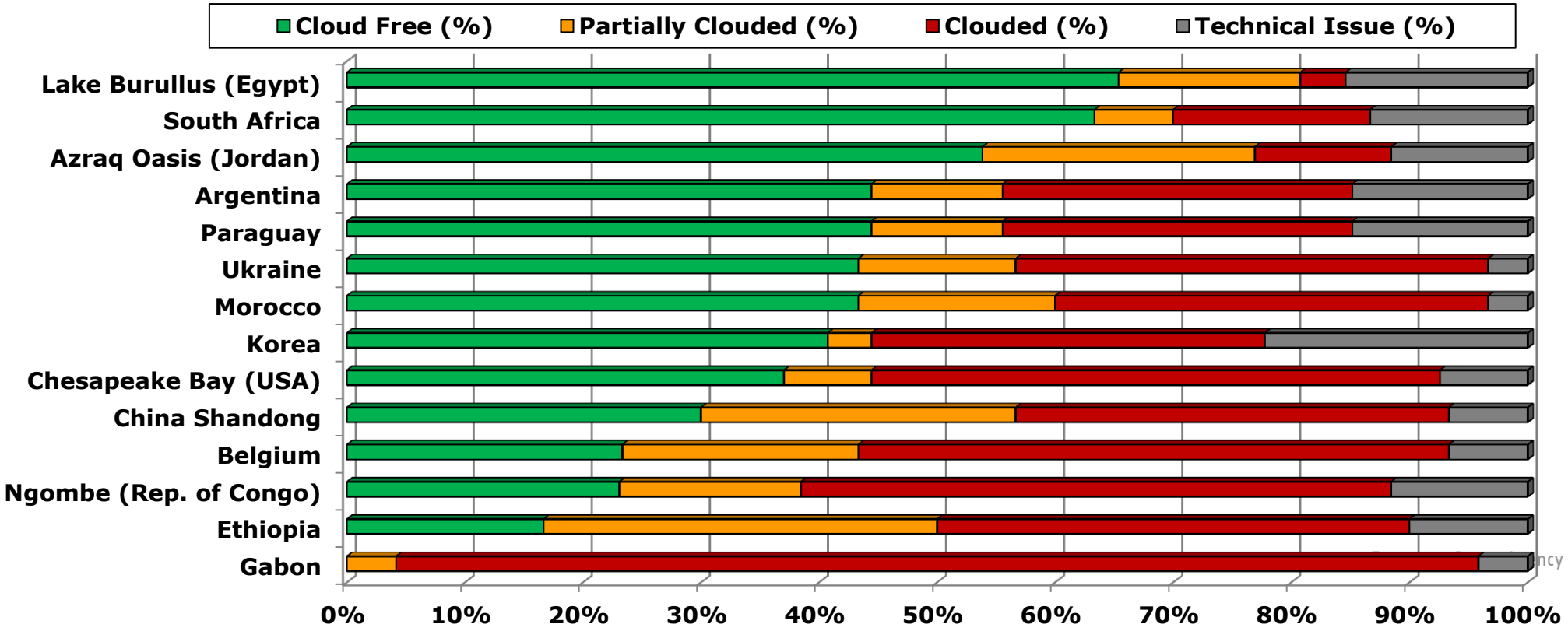
	Swath	Resolution	Bands	Revisit
Sentinel-2	***290 km***	***10 m - 20 m***	***13***	***5 days***
RapidEye	*65 km*	***5 m***	*5*	***5 days***
SPOT-4	*60 km*	*20 m*	*4*	***5 days***
Landsat-8	*185 km*	*30 m*	***11***	*16 days*

All freely available



Overview of S2 Time Series: RapidEye

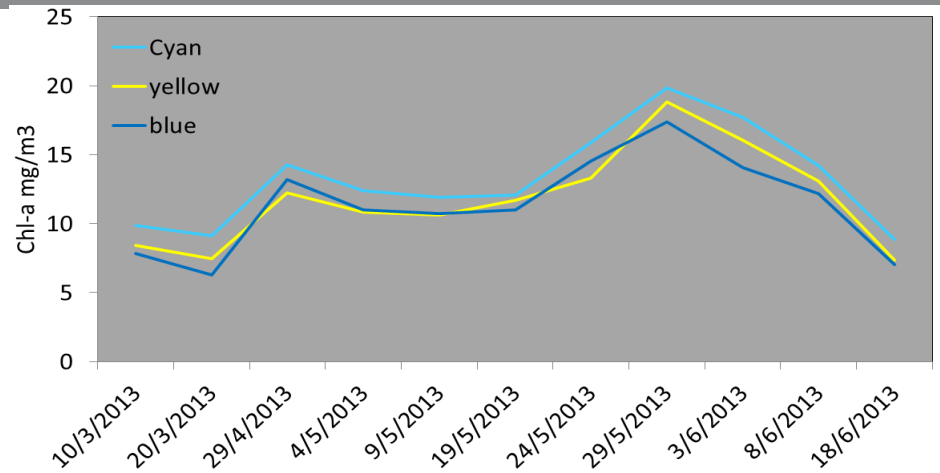
- Total of 390 acquisitions, 24-30 per site
- 38% cloud free of total acquisitions (0-65% at site level)
- Even with 5 days repeat, low coverage over Europe during growing season

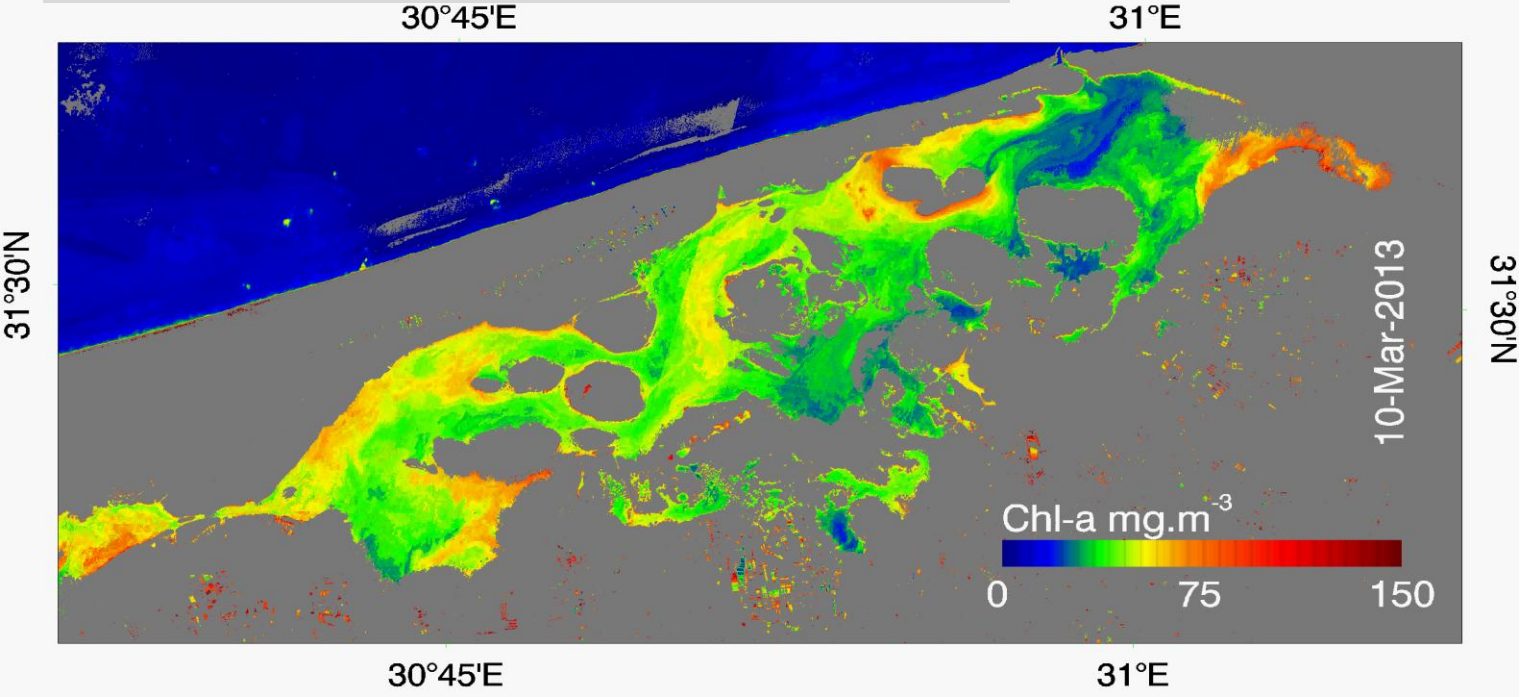


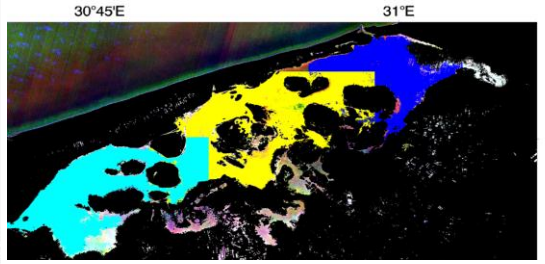
Inland Water: Spot4 products of Chl-a
(preliminary results)

Spring and summer blooms are shown for three spatially averaged regions

The regions seem to have the same temporal behavior
The start of the summer bloom is delayed in the middle region



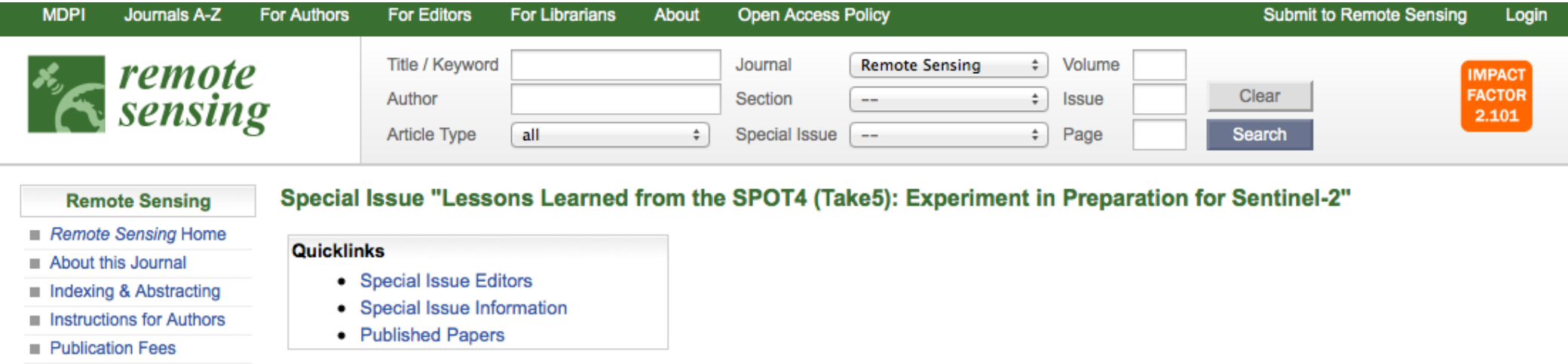




Farag,H. and Salama, M.S.,(2014) Sentinel-2 Red-Edge Bands Capabilities on Retrieving Chlorophyll-a in Turbid Water, Case Study: Lake Burullus, Egypt. *In preparation*.

TIGER AFRICA
European Space Agency

Special Issue: In Preparation of S2
Remote Sensing Journal



This Special Issue calls for lessons learned from Take5 experiment:

- pre-processing methods (ortho-rectification, atmospheric correction, cloud detection, monthly syntheses)
- calibration and validation of reflectance and bio-physical variables
- suitability of Sentinel-2 time series as a function of applications
- new processing methods for applications of time series of high resolution images

http://www.mdpi.com/journal/remotesensing/special_issues/spot4

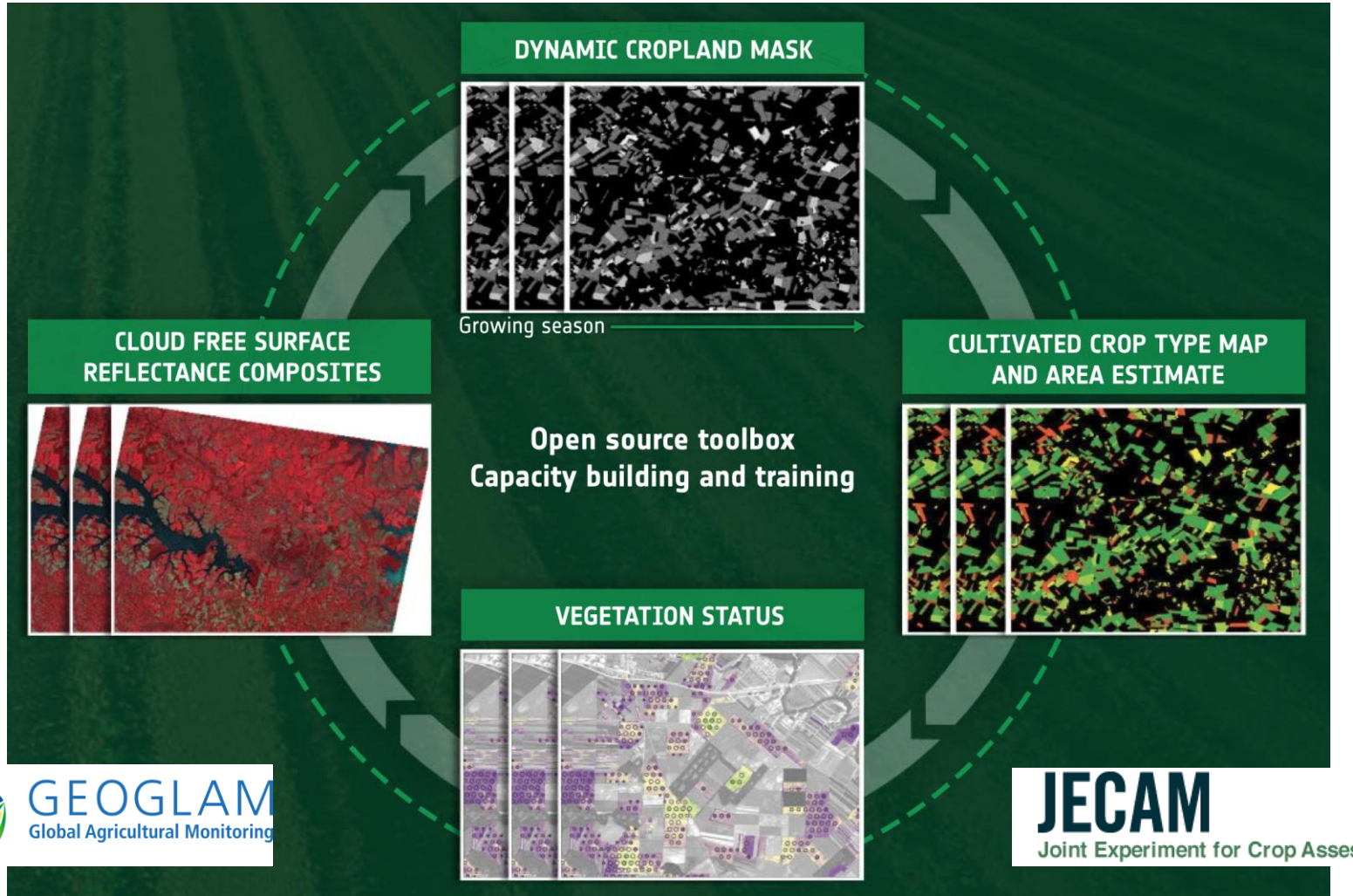
sentinel-2

→ AGRICULTURE

Sentinel-2 for Agriculture
R&D and tools

esa

Towards exploitation of Sentinel-2 for local to global agricultural monitoring – a contribution to GEOGLAM



Project

UCL Université catholique de Louvain

CESBIO

CS

CS ROMÂNIA

Key Users

FAO FIAT PANIS

WFP

IFAD Enabling poor rural people to overcome poverty

JRC EUROPEAN COMMISSION

cirad AGRICULTURAL RESEARCH FOR DEVELOPMENT

FEWS NET FAMINE EARLY WARNING SYSTEMS NETWORK

RCMRD

GEOGLAM Global Agricultural Monitoring

JECAM Joint Experiment for Crop Assessment and Monitoring

sentinel-2

→ AGRICULTURE

Sentinel-2 for Agriculture: Objectives & Concept

esa

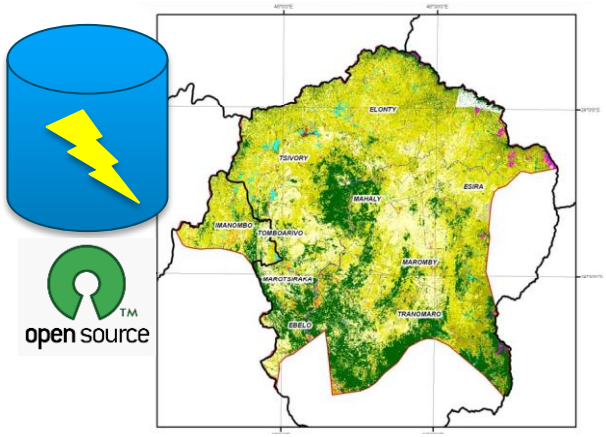
Algorithm Development

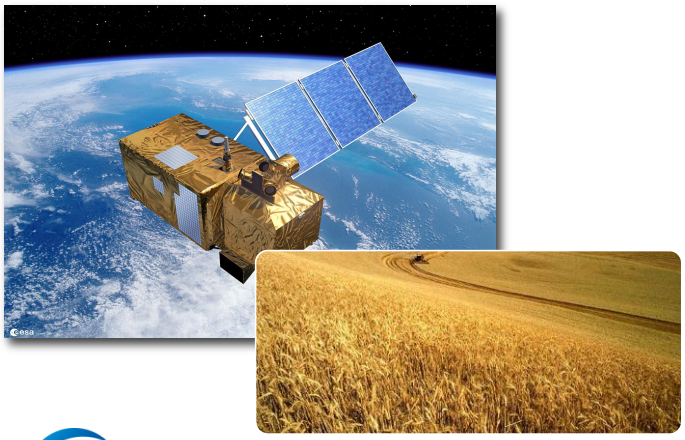
Prototypes of EO products

Demonstration & Validation

JECAM

Joint Experiment for Crop Assessment and Monitoring





GEOGLAM

Global Agricultural Monitoring

Main Design Activities:

- User Requirements
- EO product specification
- Algorithm Development

Processing System:

- 4 agricultural EO products
- Open source system
- Testing & validating of EO prototypes (12 sites)

Use cases:

- 3 national coverages & 5 local sites (290x290 km)
- Validation of EO products
- Transfer to national users

Sentinel-2 Data volume estimation
Agriculture monitoring use cases

Preliminary estimation of **Sentinel-2 data**	**Local Case (290x290 km)**	**National Case (500 000 km²)**
Single observation (level 1C)	≈ 3,5 GBytes	≈ 21 GBytes
6 months time series with 5 days cycle	≈ **128 GBytes**	≈ **762 GBytes**
Monthly surface reflectance composite	≈ 56 GBytes	≈ 335 GBytes
10-d vegetation status product (6 months)	≈ 76 GBytes	≈ 455 GBytes
Monthly dynamic cropland masks	≈ 5 GBytes	≈ 30 GBytes
Cultivated crop type and area indicator	**≈ 0,8 GBytes**	**≈ 5 GBytes**

=> Data volume reduction from L2 to L3 but mainly from L3 to L4

=> Need a large bandwidth to retrieve S2 product and disseminate output

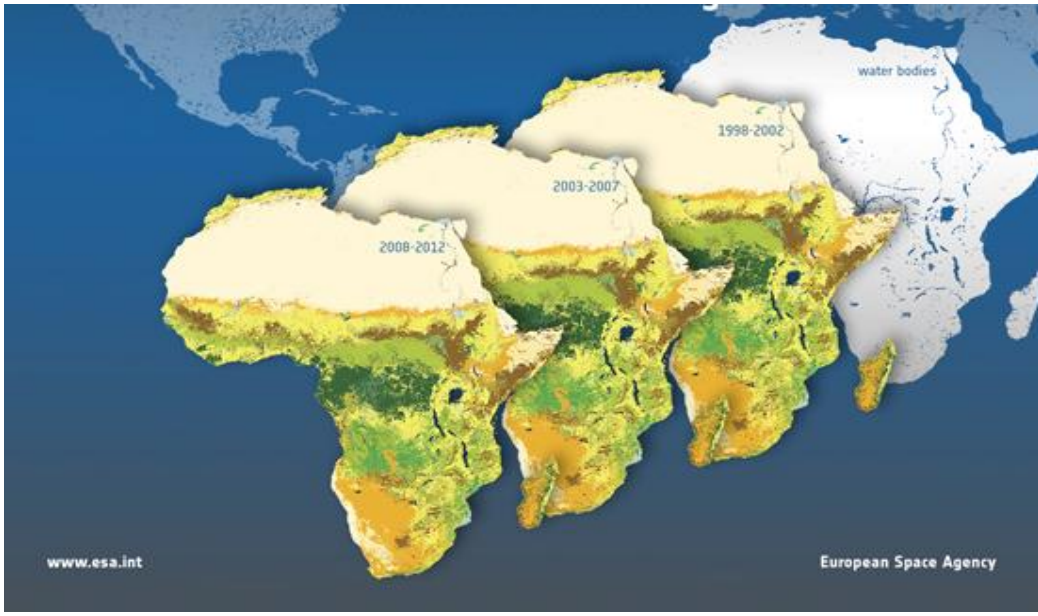
Sentinel-2 for Climate Change
CCI Land Cover

Multiyear Global Land Cover Mapping

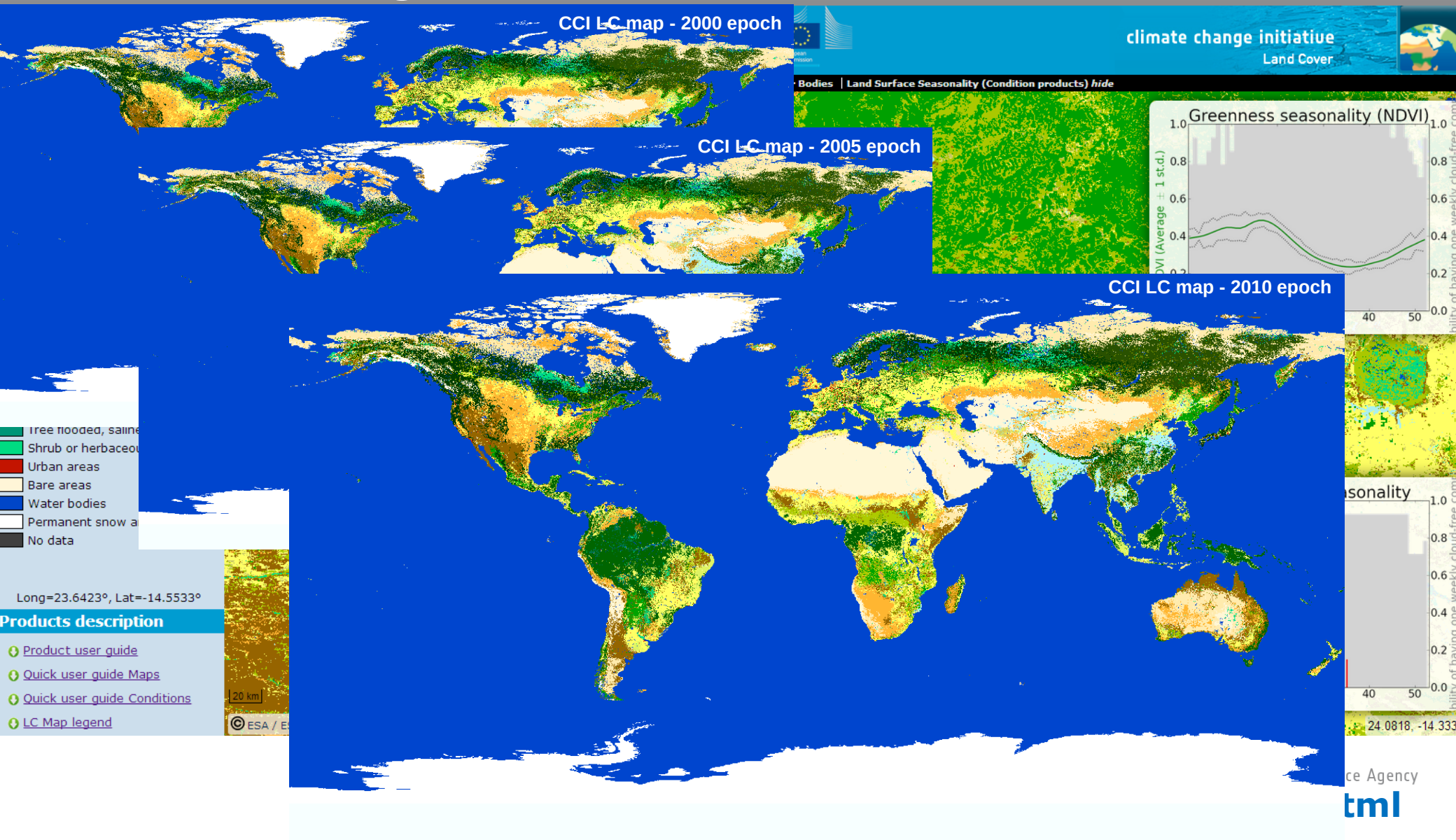
- 3 consistent global land cover products (P1:2000, 2005, 2010 & P2:1980, 1990, 2015)
- Global map of open permanent water bodies
- Development of an online validation tool

Land Cover @ 10/20m for Africa

- Land cover product over Africa using S2 + L8
- User requirement target = 30 m
- HR relevant for Climate impact assessment & Mitigation strategy
- Analyze L8-S2 geolocation accuracy & inter-calibration
- Adaptation of L-8 & S2 preprocessing (cloud detection, Atm-Corr, BRDF)

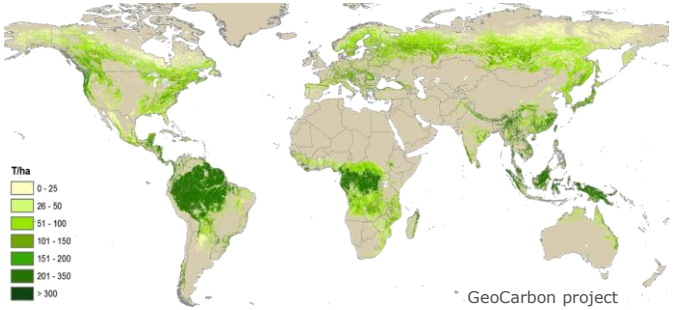


CCI Land cover results
300 meter global



R&D for International Environmental Conventions (UNFCCC, UNCCD, UNCBD, Ramsar)

GLOBBIOMASS

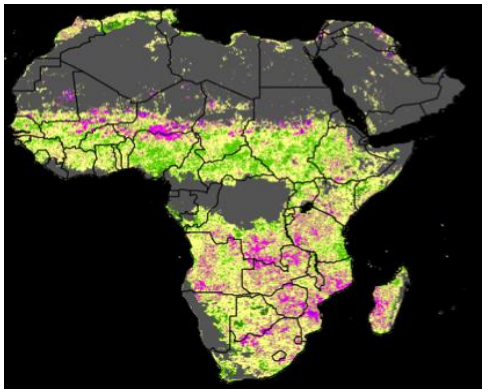


KO: Q3 2014

Budget: €1,500,000

Duration: 3 years

GLOBWETLAND AFRICA

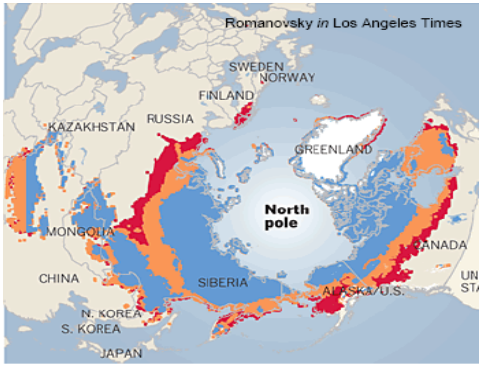


KO: Q4 2014

Budget: €1,500,000

Duration: 3 years

DUE PERMAFROST



KO: Q1 2015

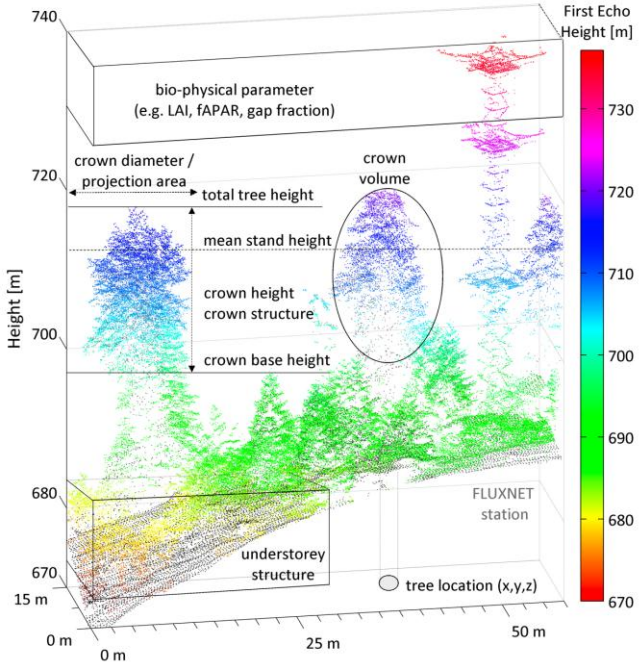
Budget: €1,000,000

Duration: 3 years

Sentinel-2 algorithm development & L2b validation

3d vegetation lab

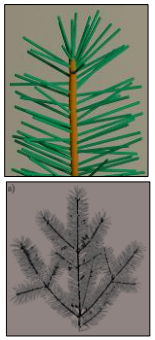
support to science element

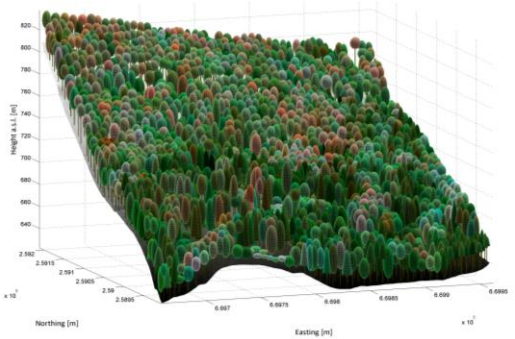


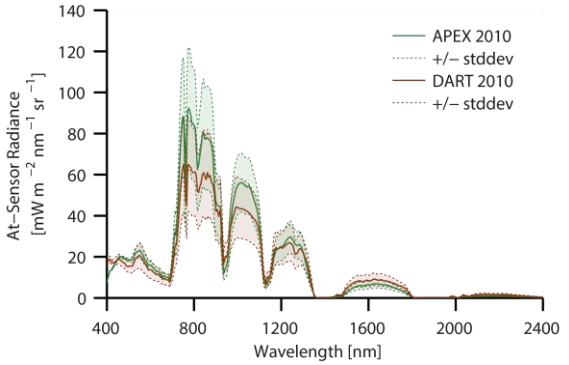
Schneider, F.D., Leiterer, R., Morsdorf, F., Gastellu-Etchegorry, J.-P., Lauret, N., Pfeifer, N., Schaepman, M.E. (2014). Simulating imaging spectrometer data: 3D forest modeling based on LiDAR and in situ data. *Remote Sensing of Environment, accepted*

http://www.geo.uzh.ch/microsite/3dveglab/index.html

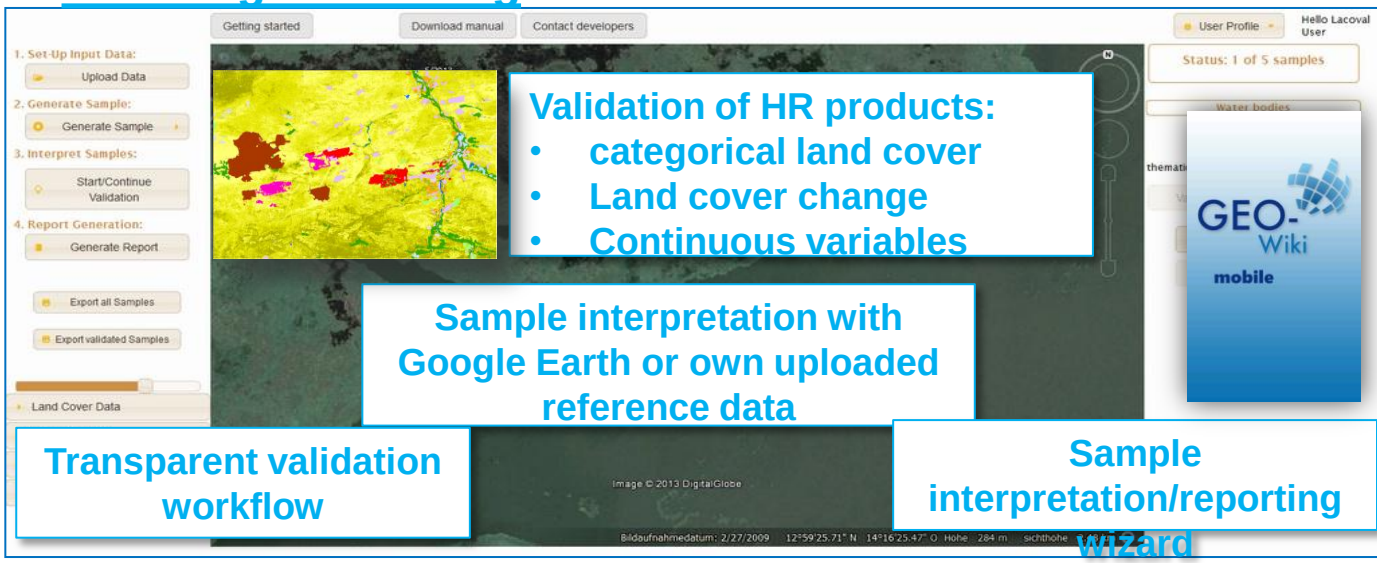
3D Reconstruction of Reference site → Simulation of current & future EO missions → Algorithm development & benchmarking







Open Source Validation tool on Geo-Wiki portal: lacoval.geo-wiki.org

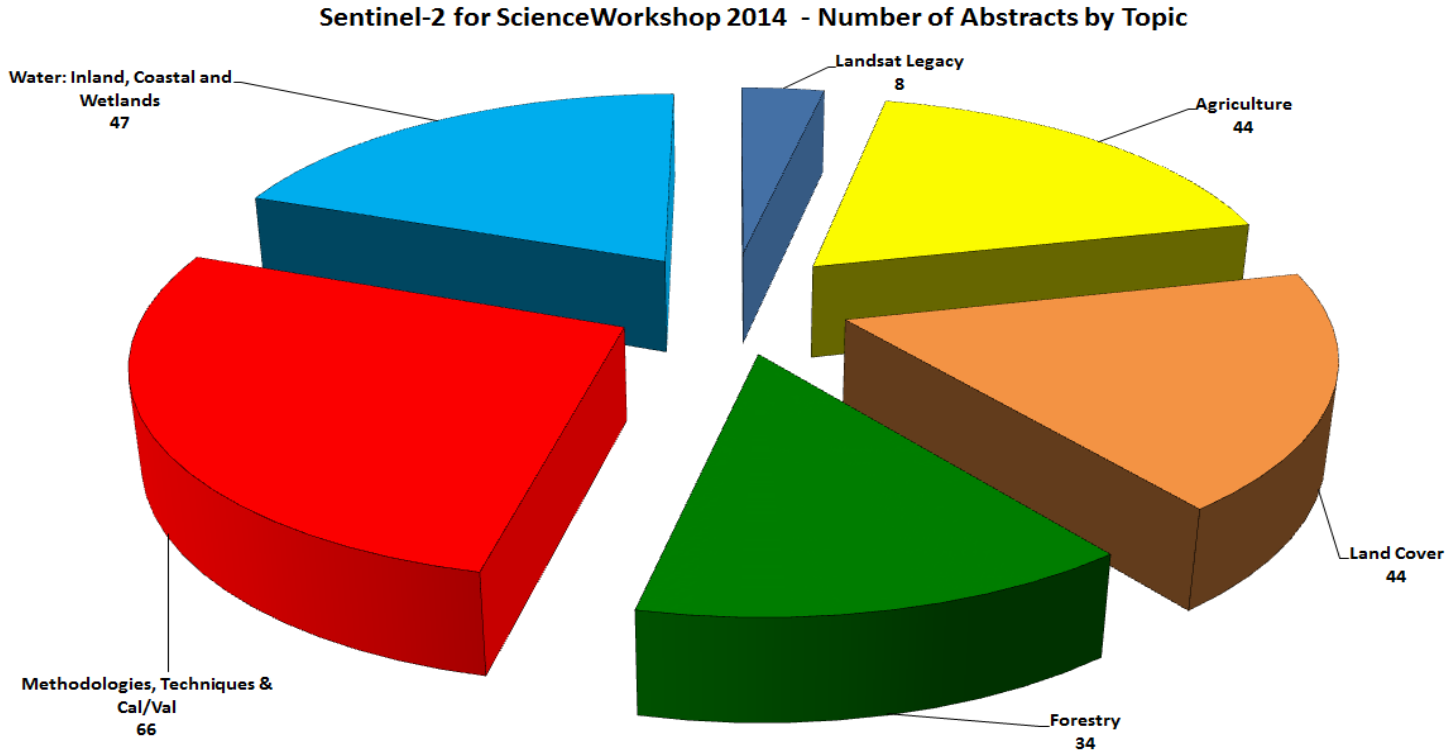


Sentinel-2 Science Community
Sentinel-2 Science Workshops: 2012 & 2014

http://www.s2symposium.org

http://seom.esa.int/S2forScience2014

Workshop 2014: 377 international attendees from 44 different countries



uropean Space Agency

Sentinel-2 Science Community
Summary & Recommendations

S2 Workshop 2012:

- 28 recommendations (http://www.s2symposium.org) – 18 addressed
  e.g. data policy, time series analysis, L8-S2 inter-calibration

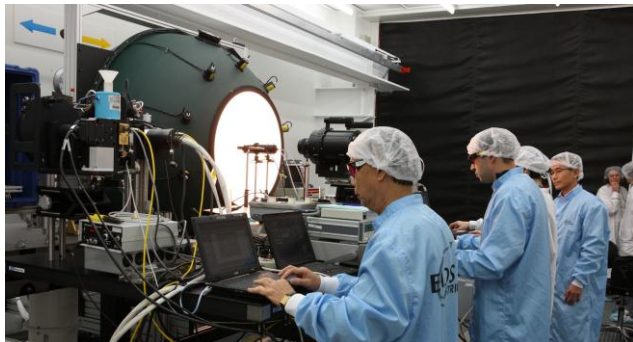
S2 Workshop 2014:

#	Main Recommendations
1	Emphasized Free & open data policy as well as efficient data access
2	Operational production of Level 2A (comparison exercises to develop community accepted best practices)
3	Tools and techniques for seamless use of Landsat and Sentinel-2 (compositing, cross-validation, compatibility of processing, time series)
4	Centralised and transparent CAL/VAL monitoring for the duration of Sentinel Program
5	Hosted processing - „bringing the algorithm to the data" as well as for standard L3 products
6	Improved atmospheric correction - including over water surfaces
7	Synergy with SAR data and sensors at varying resolution

NASA & ESA Sentinel-2 Research Cooperation

- Interest for **cooperation on joint R&D on S2 & L8** (NASA, Earsel LCLUC workshop, S2 Science Workshop)
- Algorithm development for composites and higher-level products based on S2 & L8
- Possibility for **parallel calls from ESA & NASA**
  - NASA: Land imaging science call in fall 2014,
  - ESA: S2-4SCI Land call in Q3/4 2014
  - Identify synergy and create complementarity in the calls. Encourage joint European-US teams
- **Ongoing collaboration** w/ NASA (JPPG) on S2/L8 data processing, Cal/Val, thermal convey study, Landsat 5/7/8 acquisition & processing

S2-L8 cross calibration



ESA Sentinel-2 R&D Opportunities

Innovator call (currently open, €2,4 M)

- Respond to R&D agenda of major international initiatives
- R&D preparatory activities for S1 & S2 exploitation

Scientific Toolbox Development

S-2 Toolbox (interoperable with S-1, S-3 Toolbox) – 1st Release Sep. 2014
€ 550,000, 36 months, Kick Off Feb 2014
open/source, multi-mission,

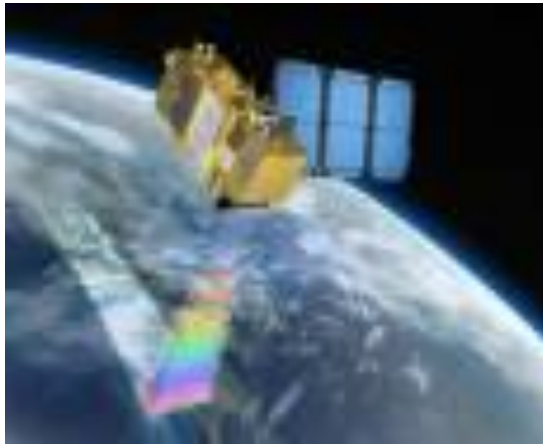
Research & Development Studies

- **S2-4SCI Land (€ 1,2 M - Q4 2014):** proposed topics - Vegetation parameters, Classification, Calibrat./Validat., Cloud screening, Atmospheric Correction, Inland Water
- **SY-4SCI Synergy (€ 1 M under selection):** S2-3 Synergy Land Product, S1-2 Synergy Land Product, S1-2-3 Ocean Virtual Lab

Conclusions: Sentinel-2

Operational Observations from Sentinel-2

- **Long-term, continuous & systematic information from local to global scale**
- **Responding to main user requirements – Land cover, Agriculture, Forest, Biodiversity, Lakes/coastal waters**
- **Open data policy & long-term continuity for sustainable uptake**



Preparatory activities for full exploitation

- **R&D for optimized and validated EO products**
- **Interoperability with Landsat (frequency, historic archive)**
- **Facilitation of EO data access & handling**

esa Sentinel Online

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Welcome to Sentinel Online

Welcome to Sentinel Online, the ESA Sentinel website.

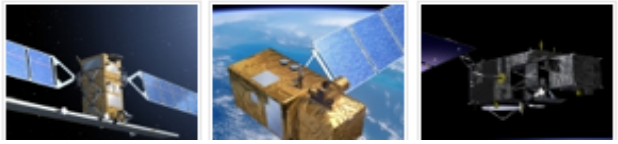
The site is constructed in such a way as to enable you to navigate easily through a variety of topics related to each Mission, Instrument, and their associated Data, as well as highlighting the Copernicus Thematic Areas served by the Missions. For more information see About sentinel online.

The GMES (Global Monitoring for Environment and Security) program has been recently renamed by the European Union to 'Copernicus'. It shall be noted that currently the content of this Website refers to the terms GMES and Copernicus alongside.

Sentinel News

- Apply for 'Sentinel-1 Student Transponders'
- Turning up the heat on Europe's first Sentinel
- Green light for GMES Copernicus
- International effort helps users get ready for
- Greece's ups and downs
- Securing operational EU funding for GMES
- ESA-NASA collaboration fosters comparable

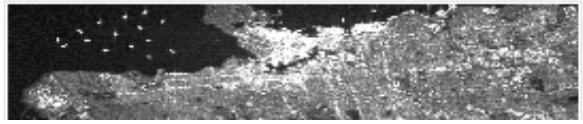
Sentinel Missions



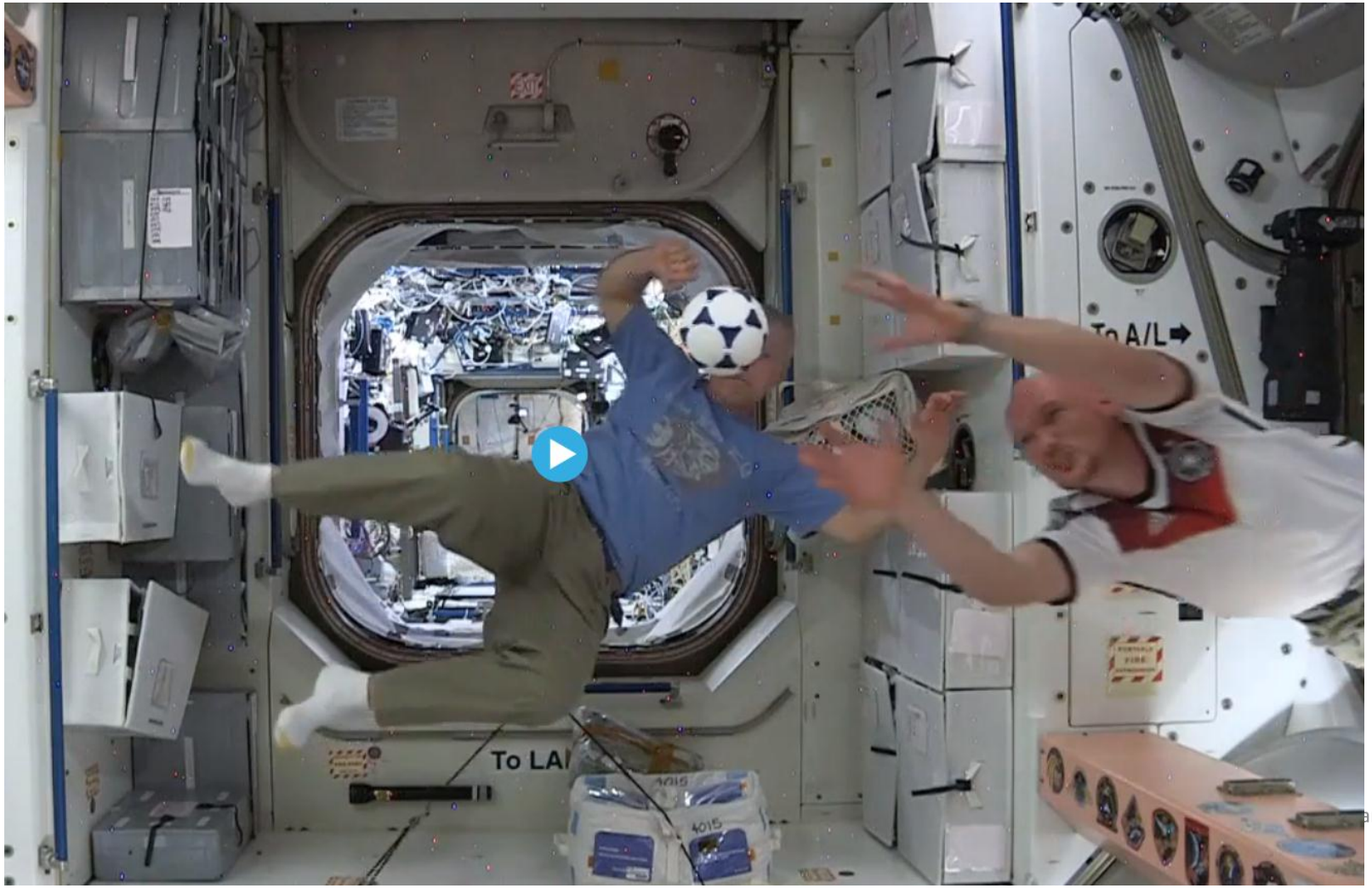
Sentinel Data Products

Featured Image

- Vancouver Radar Image
- ESA EO Image Gallery



http://sentinel.esa.int

European Space Agency

BACKUP Slides